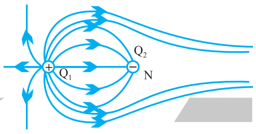


Unit I and II

Section - 1

KEY POINTS

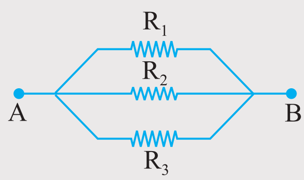
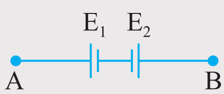
Quantization of charge	$q = \pm ne$	C
Coulomb's force	$\lvert F \rvert = \dfrac{kq_1q_2}{r^2}$	N
In vector form	$\vec{F}_{12} = \dfrac{kq_1q_2}{r_{21}^3}\vec{r}_{21} = \dfrac{kq_1q_2}{r_{21}^2}.\hat{r}_{21}$	
Dielectric constant (or relative permitivity)	$K_D = \in_r = \dfrac{F_0}{F_m} = \dfrac{\in_m}{\in_0} = \dfrac{C_m}{C_0} = \dfrac{\phi_0}{\phi_m} = \dfrac{E_0}{E_m}$	Unit less
Hence $F_0 \geq F_m$ as free space has minimum permitivity		
Linear charge density	$\lambda = \dfrac{q}{L}$	Cm^{-1}
Surface charge density	$\sigma = \dfrac{q}{A}$	Cm^{-2}
Volume charge density	$\rho = \dfrac{q}{V}$	Cm^{-3}
Electric field due to a point charge	$\vec{E} = \underset{q_0 \to 0}{\text{Lt}} \dfrac{\vec{F}}{q_0}$ (theoretical) $\left(\text{In numerical, we use } E = \dfrac{kq_1}{r^2}\right)$	

The components of electric field,	$E_x = \frac{1}{4\pi\epsilon_0}\frac{q\hat{x}}{r^3}, E_y = \frac{1}{4\pi\epsilon_0}\frac{q\hat{y}}{r^3},$ $E_z = \frac{1}{4\pi\epsilon_0}\frac{q\hat{z}}{r^3}$	NC^{-1}
Torque on a dipole in a uniform electric field	$\vec{\tau} = \vec{p} \times \vec{E}$ (or $\tau = pE \sin\theta$)	Nm
Electric dipole moment	$\vec{p} = q \cdot (2\vec{a})$ or $\vert\vec{p}\vert = q(2a)$	Cm
Potential energy of a dipole in a uniform electric field	$U = -\vec{p} \cdot \vec{E}$ (or $U = -pE\cos\theta$)	J
Electric field on axial line of an electric dipole	$E_{axial} = \frac{1}{4\pi\epsilon_0}\frac{2pr}{(r^2 - a^2)^2}$ When $2a << r$, $E_{axial} = \frac{1}{4\pi\epsilon_0}\frac{2p}{r^3}$	NC^{-1}
Electric field on equatorial line of an electric dipole	$E_{equatorial} = \frac{1}{4\pi\epsilon_0}\frac{q2a}{(r^2 + a^2)^{\frac{3}{2}}}$ When $2a << r$, $E_{equatorial}$ $= \frac{1}{4\pi\epsilon_0}\frac{p}{r^3}$	
Electric field as a gradient of potential	$E = -\frac{dV}{dr}$ or $\vec{E} \cdot d\vec{r} = -dV$	
Electric potential differences between ponts A & B	$V_A - V_B = -\frac{W_{AB}}{q_0}$	Volts (or JC^{-1})
Electric potential at a point	$V_A = \frac{1}{4\pi\epsilon_0}\frac{q}{r_A} = \frac{W_{A\infty}}{q}$	

Common potential	$V = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}$	
Electric potential due to a system of charges	$V = \dfrac{1}{4\pi \epsilon_0} \sum_{i=1}^{n} \dfrac{q_i}{r_i}$	
Electric potential at any point due to an electric dipole	$V = \dfrac{1}{4\pi \varepsilon_0} \dfrac{p\cos\theta}{(r^2 - a^2\cos^2\theta)}$ When, $\theta = 0°$ or $\theta = 180°$, $V = \dfrac{\pm 1}{4\pi \epsilon_0} \dfrac{p}{(r^2 - a^2)}$ If $r >> a$, $V = \dfrac{1}{4\pi \epsilon_0} \dfrac{p}{r^2}$ When, $\theta = 90°$, $V_{equi} = 0$	
Total electric flux through a closed surface S	$\phi_e = \oint \vec{E} . d\vec{S} = \dfrac{q_{net}}{\epsilon_0}$ q_{net} = Net charge enclosed by a $\Rightarrow$ Gaussian surface	Nm^2C^{-1}
Electric field due to line charge	$E = \dfrac{1}{2\pi\epsilon_0} \dfrac{\lambda}{r}$	NC^{-1} (or V/m)
Electric field due to an infinite plane sheet of charge	$E = \dfrac{\sigma}{2\epsilon_0}$	
Electric field between two infinitely charged plane parallel sheets having change density +s and –s	$E = \dfrac{\sigma}{\epsilon_0}$	
Electric field due to a uniformly charged spherical shell	$E = \dfrac{\sigma}{\epsilon_0} \dfrac{R^2}{r^2}$ When $r = R$, $E_0 = \dfrac{\sigma}{\epsilon_0}$ When $r < R$, $E \times 4\pi r^2 = 0$ $\therefore E = 0$	

Loss of energy (in Parallel compinaton of two capacitors	$\Delta U = \frac{1}{2}\frac{C_1C_2}{(C_1+C_2)}(V_1-V_2)^2$	
Electrical capacitance	$C = \frac{q}{V}$	F(SI Unit)
Capacitance of an isolated sphere	$C_0 = 4\pi\in_0 r$	
Capacitance of a parallel plate	$C = \frac{A\in_0}{d}$	
Capacitors in series	$\frac{1}{C} = \frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}$	
Capacitors in parallel	$C = C_1 + C_2 + C_3$	
Capacitance of a parallel plate capacitor with dielectric slab between plates	$C = \frac{\in_0 A}{d - t\left(1-\frac{1}{K_D}\right)}$	
Capacitance of a parallel plate capacitor with conducting slab between plates	$C = \frac{C_0}{\left(1-\frac{t}{d}\right)}$	
Energy stored in a charged capacitor	$U = \frac{q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}qV$	J
Resultant electric field in a polarised dielectric slab	$\vec{E} = \vec{E}_0 - \vec{E}_p$, where	Cm^{-1}
	$\overline{E}_0$ = Applied electric field and	
	$\overline{E}_p$ = Electric field due to	
polarization		
Polarization density	$P = \in_0 \chi E$	Vm^{-1} or Nc^{-1}
Dielectric constant (in terms of electric susceptibility or atomic polarisability)	$K_D = 1 + \chi$ Where K is dieletric Contant	

CURRENT ELECTRICITY
IMPORTANT FORMULA

1. Drift Velocity	$\vec{v}_d = -\frac{e\vec{E}}{m}\tau$	$\vec{E}$ – electric fluid
		τ = Relaxation time
2. Relation b/w current and Drift Velocity	$I = neAv_d$	e = charge on electrons. m = mass of electron n = number density of electrons
3. Ohm's Law	$V = RI$	A = Cross Section Area
4. Resistance	$R = \frac{\rho l}{A}$	V = potential difference across conductor
5. Specific Resistance or Resistivity	$\rho = \frac{RA}{l} = \frac{m}{ne^2\tau}$	l = length of conductor
6. Current density	$j = I/A = neV_d$	
7. Electrical Conductivity	$\sigma = 1/\rho$	
8. Resistances in Series	$R_{eq} = R_1 + R_2 + R_3$	
Parallel Combination	$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	
9. Temperature Dependance of Resistance	$R_t = R_0(1 + \alpha t)$	R_t = Resistance at t°C a = Cofficent of temprature t = Temperature
10. Internal Resistance of a cell	$r = \left(\frac{E}{V} - 1\right)R$	R_o = Resistance at 0°C
11. Power	$P = VI = I^2R = \frac{V^2}{R}$	
12. Cells in Series	$Eeq = E_1 + E_2$	
Equivalent emf	$Eeq = E_1 - E_2$	$E_1 > E_2$ 
Equivalent Internal Resistance	$r_{eq} = r_1 + r_2$	E_1 & E_2 are emf of two cells
Mobility (μ)	$\frac{v_d}{E}$	CGS unit → $Cm^2s^{-1}v^{-1}$ SI unit → $M^2s^{-1}s^{-}v^{-1}$

		r_1 and r_2 are their internal resistances respectively
Equivalent Current	$I = \frac{nE}{R + nr}$	n = no. of cells in series.
13. Cells in parallel	Equivalent e.m.f. $E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$ Equivalent resistance $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$	
Equivalent Current	$I = \frac{mE}{mR + r}$	m = number of cells in parallel
14. Kirchhoff's Laws	$\Sigma i = 0$ (at a junction) $\Sigma iR = \Sigma E$ or $\Sigma iR = 0$ (in a closed loop)	i = Current R = Resistance E = e.m.f.
15. Wheatstone Bridge (balanced condition)	$\frac{P}{Q} = \frac{R}{S}$	P, Q, R and S are resistances in Ohm in four arms of Wheatstone Bridge.

UNIT–I & UNIT–II

ELECTROSTATICS AND CURRENT ELECTRICITY

QUESTIONS

(SECTION - A)

VERY SHORT ANSWER QUESTIONS (1 MARK)

1. Two point charges repel each other with a force 'F' when placed in a medium of dielectric constant K. What will be the force between them when placed the same distance apart in air.

   (a) F (b) KF

   (c) $\frac{F}{K}$ (d) $\frac{F}{F}$

2. An electron and a proton are released from rest in a uniform electrostatic field. From the following which one is not correct.

   (a) Both will experience the same force in magnitude

   (b) Proton will have larger acceleration

   (c) Electron will have larger acceleration

   (d) Proton and electron will move in opposite direction

3. A charge q is distributed over a metal sphere of radius R. The electric field and the electric potential at the centre are:

   (a) $E = 0, V = 0$ (b) $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}, V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$

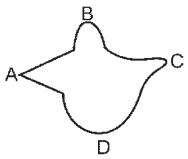
   (c) $E = 0, V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$ (d) $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}, V = 0$

4. An electric dipele having charages $\pm 2\mu C$ is placed inside a sphere of radius 2m, the net electric flux linked with the sphere is

   (a) 2.26×10^5 Nm^2C^{-2} (b) 2.26×10^{11} Nm^2C^{-2}

   (c) 4.56×10^5 nm^2C^{-2} (d) 0

5. In the metallic conductor shown in thefiruge is continously charged. From which of the following points A, B, C and D does the charge leak first?



(a) A (b) B

(c) C (d) D

6. The electric field due to an electric dipole ($\pm q$, $2a$) at a point on equatorial line at distance 'r' from centre of dipole (a < < r) is E. The electric field due to the dipole at distance '2r' on axial line is

(a) 2E (b) $\frac{E}{2}$

(c) $\frac{E}{4}$ (d) $\frac{E}{8}$

7. In Gause's law $\oint \bar{E}.d\bar{s} = \frac{q}{\varepsilon_0}$, the electric field is

(a) Due to the charges inside the surface only

(b) Due to the changes outside the surface only

(c) Due to all the charges inside and outside the surface

(d) Due to the charges on the surface only

8. An electric dipole is placed in extermal uniform electric field in stable equilibrium position. The potential energy of dipole is

(a) –PE (b) PE

(c) –2PE (d) 0

9. The electric flux linked with a sphere of radius 1 m and charge of 17.7×10^{-10}C at its enetre is : ($\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2 N^{-1} m^{-2}$)

(a) 0.02 Nm^2C^{-1} (b) 2.00Nm^2C^{-1}

(c) 200 Nm^2C^{-1} (d) 2000 Nm^2C^{-1}

10. Which charge configuration produces a uniform electric field?

(a) a point charge

(b) infinite unifrom line charge

(c) uniformly charged spherical shell

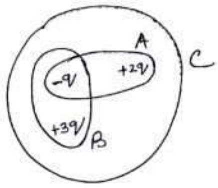
(d) uniformly charged infinite plane sheet

11. An electric dipole is placed in an electric field of 2×10^5 N/C at an angle of 30° with the direction of field. If dipole length is 1 cm and it experiences a torque of 8Nm, the charge on dipole is

(a) 8 mC (b) 6 mC

(c) 4 mC (d) 2 mC

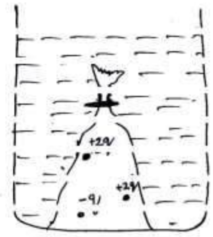
12. From the given figure, find the ratio of electric flux through the Gaussian surfaces A, B & C.



(a) 3 : 4 : 6 (b) 2 : 3 : 5

(c) 1 : 2 : 3 (d) 1 : 2 : 4

13. The total electric flux through the closed surface which is kept inside the water (as shown in the firuge) is :



(a) $\frac{5q}{81\varepsilon_0}$ (b) $\frac{q}{27\varepsilon_0}$

(c) $\frac{27q}{\varepsilon_0}$ (d) $\frac{81q}{\varepsilon_0}$

14. Two charged particles havign charges +q and –q are separated by a distance 'r' in air. If they are touched together and then separated to the same distance, the force between them will be

(a) Less than before (b) More than before

(c) Same as before (d) Zero

15. Two points A and B are maintained at a potential of 6V and –4V respectively. The work done in moving are electron from A to B is

(a) 1.6×10^{-18}J (b) -1.6×10^{-18}J

(c) 1.6×10^{-20}J (d) -1.6×10^{-20}J

16. If the voltage applied on a capacitor is incrased from 1V to 2V, choose the correct option

(a) Charge remains the same

(b) Capacitance remains the same

(c) Both charge and capacitance remains same

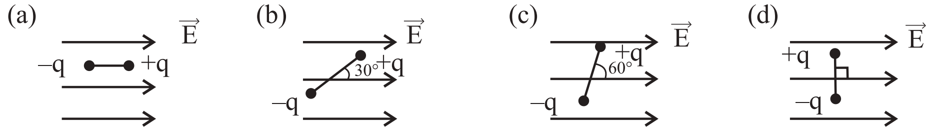
(d) Both charge and capacitance will be doubled

17. Electric dipole moment of $CuSO_4$ molecule is 3.2×10^{-28} C-m. Find the separation between copper and sulphate ions.

(a) 2nm (b) 1 nm

(c) 0.5 nm (d) 0.25 nm

18. An electric dipole is placed in uniform external electric field. From the following diagrams,which one represent half the maximum torque on the dipole.



19. A parallel plate capacitor is charged by a battery and the battery is disconnected. Now the area of the plates of capacitor and the distance between the plates of capacitor are doubled. Which quantity will change?

(a) Capacitance (b) Voltage

(c) energy (d) energy density

20. A positively charged particel is released from rest in a uniform electric field. The electric potential energy of the charge will

(a) remain same (b) increase

(c) decrease (d) become zero

21. Equipotentials at large distance from a collection of charges whose total sum is not zero, are approximately

(a) Spheres (b) Planes

(c) Parabolids (d) ellipsoids

22. Two small identical spheres each carrying a chare 2μC are placed 1 m apart in air. If one of the spheres is taken around the other one in a circular path of radius 1 m, the work done will be equal to

(a) 0.036J (b) 0.36J

(c) 3.6 J (d) Zero

23. A hollow metal sphere of raidus 5 cm is charged so that the potential on its surface is 9V. The potential at the centre of sphere is

(a) Same as at a point 3 cm from the centre of sphere

(b) Same as at a point 5 cm away from the surface of sphere

(c) Some as at a point 3 cm away from the sufrace of sphere

(d) Zero

24. N identical drops each having a charge q and potential V coalesec to form a big drop.

The charge and potential on big drop will be:

(a) Nq, NV respectively (b) Nq, $N^{1/3}$V respectively

(c) Nq, $N^{2/3}$V respectively (d) Nq, V/N respectively

25. A capacitor is charged by using a battery. Battery is disconnected from the capacitor then a dielectric slab is inserted between the plates of capacitor, which results in

(a) decrease in potential difference across the plate

(b) decrease in stored potential energy

(c) bath (a) and (b)

(d) neither (a) nor (b)

26. The work done in bringing a unit positive charge from infinite distance to a point at distance r from a positive charge q is W. The potential at that point is

(a) $\frac{W}{q}$ (b) qW

(c) W (d) $\frac{Wq}{r}$

27. The radii of two metallic spheres of are 10 cm and 15 cm and carrying charge of 75 μC each. If they are shorted then the charge will be transferred

(a) 15 μc from bigger to smaller sphere

(b) 15 μc from smaller to bigger sphere

(e) 25μc from bigger to smaller sphere

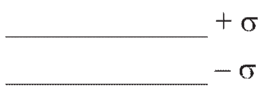
(d) 25 μc from smaller to bigger sphere

28. A proton and an α-particle are accelerated from rest through a potential difference of 100 volt. The ratio of their kinetic energy is

(a) 1:1 (b) 1:2

(c) 2:1 (d) 1:4

29. There are two conducting spheres of some radii, one is solid and the other is hollow, then



(a) More change can be given to solid sphere

(b) More charge can be given to hollow sphere

(c) Both can be charged equally to maximum

(d) None of the above

30. Two plane sheets of charge densities +σ and – σ are kept in air as shown in the figure. The electric field in the region between the plate is

(a) $\frac{\sigma}{\varepsilon_0}$

(b) $\frac{\sigma}{2\varepsilon_0}$

(c) $\frac{2\sigma}{\varepsilon_0}$

(d) Zero

31. Two copper wires with their lengths in the ratio 1:2 and their resistances are in the ratio 1:2 are connected in series with a battery. The ratio of drift velocities. of free electrons in two wires is

(a) 1:2

(b) 2:1

(c) 1:4

(d) 1:1

32. If 'n' identical cells each of emf ε and internal resistance r are commected in parallel. The equivalent emf and equivalent resectance will be

(a) $\frac{\varepsilon}{n}, \frac{r}{n}$ respectively

(b) $n\varepsilon$, nr respectively

(c) $\varepsilon, \frac{r}{n}$ respectively

(d) $n\varepsilon, \frac{r}{n}$ respectively

33. Two heating coils, one of thin wire and other of thick wire, made of same material and of same length are connected in turn to a source of emf. Then

(a) Thicker wire will produce more heat

(b) Thiner wire will produce more heat

(c) Both the wires will produce same heat

(d) No wire will produce heat

34. A steady current flour in a metallic conducter of non-emiform cross-section. Which of the quantities remain constant along the length of the conductor?

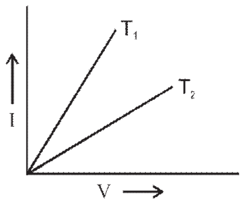
(a) drift speed only

(b) current only

(c) drift speed and current both

(d) drift speed, current and electric field

35. The I-V graph for a given metallic wire at two different temperatures T_1 and T_2 are shown in the figure, then



(a) $T_1 < T_2$

(b) $T_1 > T_2$

(c) $T_1 = T_2$

(d) $T_1 : T_2 = 2 : 1$

36. In the equation A = BC, A is the electric field, B is the current density, then c is

(a) conductivity (b) resistivity

(c) conductance (d) resistance

37. For which of the following relation between drift velocity (V_d) and electric field (E), ohm's law is obeyed

(a) $V_d \times E^{1/2}$ (b) $V_d \times E$

(c) $V_d \times E^2$ (d) $V_d \times \grave{E}^{-1}$

38. The Relaxation time in conductos

(a) increases with increase in temperature

(b) decreases with increase in temperatuure

(c) is independent of temperature

(d) First increase then decreases with increase in temperature

39. The resistance and resistivity of a given wise are R and ρ respectively. If its length and radius both are doubled, then if new resistance and resistivity are R' and ρ' respectively. Then

(a) $R' = 2R, \rho' = 2\rho$ (b) $R' = \frac{R}{2}, \rho' = \frac{\rho}{2}$

(c) $R' = 2R, \rho' = \rho$ (d) $R' = \frac{R}{2}, \rho' = \rho$

40. Kirchhoff's first law, $\sum i = 0$ at a junction and second law $\sum V = 0$ in a closed loop are based on.

(a) conservation of charge, conservation of energy respectively

(b) both on conservation of charge

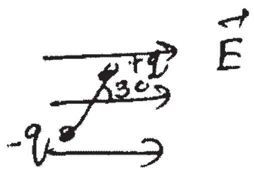
(e) conservation of charge, conservation of energy respectively

(d) Both on conservation of energy

Unit 1 & 8 Unit 2

Answers

1. (b) KF
2. (b) Proton will have larger acceleration
3. (c) E = 0, $v = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$
4. (d) 0
5. (a) A
6. (c) $\frac{E}{4}$
7. (c) Due to all charges inside and outside the surface only
8. (a) –PE
9. (c) 200 NM^2 C^{-1}
10. (d) Uniformly charged infinite plane seet
11. (a) 8 mc
12. (a) 1 : 2 : 4
13. (b) $\frac{q}{27\varepsilon_0}$
14. (d) Zero
15. (a) 1.6×10^{-18}J
16. (b) capacitance remains the same
17. (b) 1 nm
18. (b)



19. (d) energy density
20. (c) decrease
21. (a) spheres
22. (d) zero

23. (a) Same as at a point 3 cm from the centre of sphere.

24. (c) Nq, $N^{2/3}V$ respectively

25. (c) both (9) & (b)

26. (c) W

27. (b) 15 μc from smaller to bigger sphere

28. (b) 1:2

29. (c) Both can be charged equally to maximum value

30. (a) $\frac{\sigma}{\varepsilon_0}$

31. (d) 1:1

32. (c) $\varepsilon, \frac{r}{n}$ respectively

33. (a) Thicker wire was produce more heat

34. (b) current only

35. (a) $T_1 < T_2$

36. (b) resistivity

37. (b) $V_d \times E$

38. (b) decreases with increase in temperative

39. (d) $R' = \frac{R}{2}, \rho' = \rho$

40. (c) conservation of chaye, comulation of energy respectively

Assertion and Reason based questions on electrostatics

For question two statements are given one labelled Assertion A and the other labelled Reason R. Select the correct answer to these question from the codes (a), (b), (c) and (d) as given below:

a) Both A & R are true and R is correct explanation of A

b) Both A & R are true but R is not the correct explanation of A

c) A is true but R is false

d) A is false and R is also false

41. Assertion : Electrons move away from a region of lower potential to a region of higher potential.

    Reason : Because electron is a negatively charged partiels.

42. Assertion : Work done in moving any charge between two points on an equipotential surface is zero.

    Reason : Because an equipotential surface is that surface which has always zero potential at all points on it.

43. Assertion : A point charge q is placed at a distance a/2 directly above the centre of square of side a. The magnitude of electric flux associated with the square is independent of side length of the square.

    Reason : Gauss's law is independent of size of Gaussian surface.

44. Assertion : Work done in moving a change between any two points in an electrostatic field is independent of the path followed by the charge between these points.

    Reason : Electrostatic force is not conservative force.

45. Assertion : Net electric field inside a conductor is zero.

Reason : Total positive charge equals total negative charge in a charged conductor.

Answer Key :

(1) a)

(2) c)

(3) a)

(4) c)

(5) c)

Assertion and Reason Based Question on Current Electricity

For these question, two statements are given-one labelled Assertion A and the other labelled Reason (R). Select the correct answer to these question from the codes (a), (b), (c) and (d) as given below.

a) Both A and R are true and R is the correct explanation of A

b) Both A and R are true but R is NOT the correct explanation of A

c) A is true but R is false

d) A is false and R is also false

46. Assertion: An electric bulb starts glowing instantly as it is switched on.
    Reason: Drift velocity of electrons in a metallic wire is very large.

47. Assertion : When cells are connected in parallel to the external load, the effective e.m.f. increases.

    Reason : All the cells will be sending the current to the external load in the same direction.

48. Assertion : Electrons move from a region of higher potential to a region of lower potential.

    Reason : An electron has less potential energy at a point where potential is higher and vice-versa.

49. Assertion : In series combination of electric bulbs the bulb of lower power emits more light than that of higher power bulb.

    Reason : The lower power bulb in series gets more current than higher power bulb.

50. Assertion : The drift velocity of electrons in a metallic wire decreases, when temperature of the wire increases.

Reason : On increasing temperature, conductivity of metallic wire decreases.

Answer Key :

(46)	c)
(47)	d)
(48)	c)
(49)	c)
(50)	b)

CASE STUDY ELECTROSTATICS

Static Electricity : Static electricity is the build up of an electrical charge on the surface of an object. We see static electricity everyday. When our dry hairs are dressed with a plastic comb, hairs get charged. Lightning is a powerful form of static electricity. Atoms are made up of tiny particles called neutrons, protons and electrons. The neutrons and protons together form the nucleus. The electrons revolve around the outside of the nucleus. A static charge is formed when two surface are rubbed against each other and the electrons move from one object to another.

Each question carries 1 mark.

1. Which atomic particle move from one surface to another in order to form static charge?

   a) Electrons   b) Protons

   c) Neutrons   d) All of the above

2. What is static electricity?

   a) Electricity that flows in one direction

   b) Electricity that constantly changes direction

   c) An electric charge on the surface of an object

   d) Electricity that is sent over the air

3. When a charged rod is brought near a neutral paper piece, then charged rod

a) Attracts the paper piece

b) Repels the paper piece

c) Neither attract nor repel the paper piece

d) None of the above

4. Which of the following is/are practical application for static electricity?

a) Air filters b) Photocopier

c) Laser printers d) All of the above

5. Which of the following is an example of static electricity?

a) Electricity for a light bulb

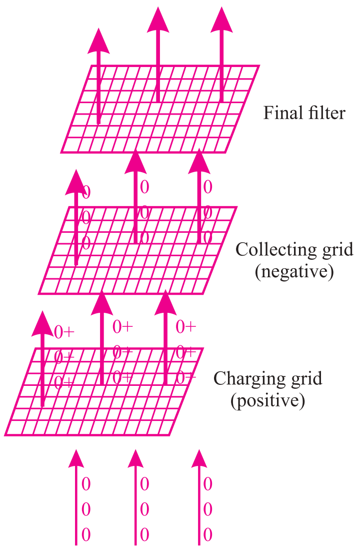
b) An electric socket in your home

c) Your pants sticking to yours legs

d) None of the above

Air Cleaner

II In cleaners, the air is passed through a grid which charges the particles in air (like as smoke, dust, pollen etc) positively (usually) and them the air is passed through oppositely charged grid that attracts and retain the charged particles. So clean air is obtained by air cleaner.



Each question carriers

1 Mark.

1. Negative charge on a body is due to

a) Excess of electrons on the body

b) deficiency of electrons on the body

c) Passing electric current through the body

d) None of the above

2. When a charged body is placed near neutral piece of paper, it attracts the paper due to

a) Electrical induction b) Self induction

c) Mutual induction d) None of the above

3. When two bodies are rubbed against each other them they get charge due to

a) Transfer of electrons b) Transfer of protons

c) Transfer of neutrons d) None of the above

4. Air cleaner works on

a) Magnetism b) current

c) Electrostatics d) Mutual induction

5. Which of the following is a practical application of static electricity?

a) Cyclotron b) Photocopier

c) Transformer d) AC Generator

Answer Key : Static Electricity

(1) a)

(2) c)

(3) a)

(4) d)

(5) c)

Answer Key : Air Cleaner

(1) a)

(2) a)

(3) a)

(4) c)

(5) b)

III. **Temperature Dependence of Resistivity**

The resistivity of a material is found to be dependent on the temperature. Different materials do not exhibit the same dependence on temperature. Over a limited range of temperatures, that is not too large, the resistivity of a metallic conductor is approximately given by $\rho_T = \rho_0[1+\alpha(T-T_0)]$

Where ρ_T is the resistivity at a temperature T and ρ_0 is the same at a reference temperature T_0. α is called the temperature co-efficient of resistivity. For the metals α is positive, meaning that resistivity increase with increasing temperature. for non metals α is negative and for some metal alloys it is very small.

1. The resistance of insulators---------

   a) increases with increase in temperature

   b) decreases with increase in temperature

   c) is independent of temperature

   d) None of the above

2. What is the unit of temperature coefficient of resistivity ?

   a) $\Omega m^{o}c^{-1}$

   b) $\Omega m^{o}c$

   c) ^{0}C

   d) $^{0}C^{-1}$

3. Standard resistance coils are made of

   a)metals

   b)insulators

   c)semiconductors

   d) alloys of metal

4. The resistance values of constantan and manganin would change ________ with temperature.

   a)very little

   b)large

   c)very large

   d) does not change

5. The resistivity of metals---------

a) decreases with decrease in temperature

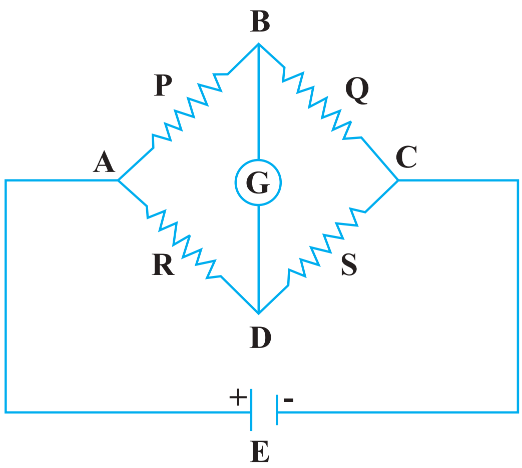
b) decreases with increase in temperature

c) is independent of temperature

d) None of the above

Answer Key : 1. (a), 2. (d), 3. (d), 4. (a), 5. (a)

IV The Wheatstone bridge works on the principle of null deflection, i.e. if the ratio of their resistances are equal and no current flows through the circuit given in figure. The working of metre bridge is based on Wheatstone bridge principle. The meter bridge is used to find the resistance of unknown conductor or to compare two unknown resistances.



1 When galvanometer shows null deflection

a) $V_B > V_D$

b) $V_B < V_D$

c) $V_B = V_D$

d) Can't be determined

2. Wheatstone bridge is a/an:

a) A.C. bridge

b) D.C bridge

c) High bridge

d) None of these

3. Whetstone bridge is used to measure resistance of various type of wires for :

a) Determining their effective resistance

b) Computing the power dissipation

c) Quality control of wire

d) None of these

4. By using variations on a Wheatstone bridge we can :

a) Measure quantities such as voltage, current and power

b) Measure high resistance values

c) Measure complex power

d) Measure quantities such as capacitance, inductance and impedance

5. The given Wheatstone bridge is said to be balanced when :

a) $\frac{P}{R} = \frac{Q}{S}$

b) P+R=Q+S

c) P-Q=R-S

d) P.R=Q.S

Answer Key

1(c) 2(b) 3(a) 4(b) 5(a)

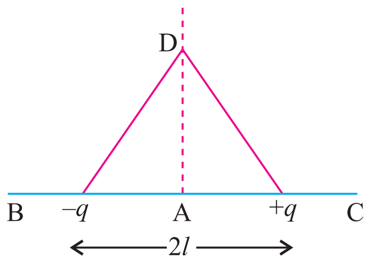
SHORT ANSWER QUESTIONS (2 MARKS)

1. An oil drop of mass *m* carrying charge – Q is to be held stationary in the gravitational field of the earth. What is the magnitude and direction of the electrostatic field required for this purpose ? **Ans.** E = mg/Q, downward
2. Draw E and V versus *r* on the same graph for a point charge.
3. Find position around dipole at which electric potential due to dipole is zero but has non zero electric field intensity.

   Ans. Equatorial position, V = 0, $\vec{E} = \frac{-1}{4\pi\epsilon_0}\frac{\vec{p}}{r^3}$ (a << *r*)

4. Derive an expression for the work done in rotating an electric dipole from its equilibrium position to an angle θ with the uniform electrostatic field.
5. A electrostatic field line can not be discontinuous.Why ?
6. A thin long conductor has linear charge density of 20 μC/m. Calculate the electric field intensity at a point 5 cm from it. Draw a graph to show variation of electric field intensity with distance from the conductor.

   Ans. 72×10^5 N/C
7. What is the ratio of electric field intensity at a point on the equatorial line to the field at a point on axial line when the points are at the same distance from the centre of the dipole ? **Ans.** 1 : 2
8. Show that the electric field intensity at a point can be given as negative of potential gradient.
9. A charged metallic sphere A having charge q_A is brought in contact with an uncharged metallic sphere of same radius and then separated by a distance *d*. What is the electrostatic force between them. **Ans.** $\frac{1}{16\pi\epsilon_0}\frac{q_A^2}{d^2}$
10. An electron and a proton travel through equal distances in the same uniform electric field E. Compare their time of travel. (Neglect gravity)
11. Two point charges – *q* and + *q* are placed 2*l* metre apart, as shown in Fig. Give the direction of electric field at points A, B, C and D, A is mid point between charges – *q* and + *q*.

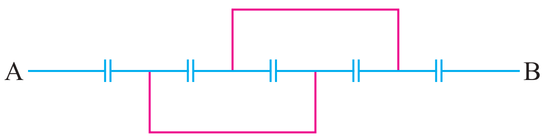


12. The electric potential V at any point in space is given $V = 20x^3$ volt, where x is in meter. Calculate the electric intensity at point P (1, 0, 2).

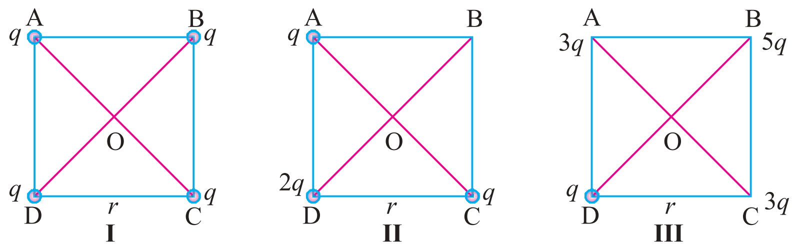
Ans. – 60 NC^{-1}

13. Justify why two equipotential surfaces cannot intersect.

14. Find equivalent capacitance between A and B in the combination given below : each capacitor is of 2 μF. **Ans.** 6/7 μF



15. What is the electric field at O in Figures (i), (ii) and (iii), ABCD is a square of side r.



Ans. (i) Zero, (ii) $\frac{4q}{4\pi\varepsilon_0 r^2}$ along OB (iii) $\frac{8q}{4\pi\varepsilon_0 r^2}$ along OD

16. What should be the charge on a sphere of radius 4 cm, so that when it is brought in contact with another sphere of radius 2 cm carrying charge of 10 μC, there is no transfer of charge from one sphere to other ?

Ans. $V_a = V_b$, Q = 20μC.

17. For an isolated parallel plate capacitor of capacitance C and potential difference V, what will be change in (i) charge on the plates (ii) potential difference across the plates (iii) electric field between the plates (iv) energy stored in the capacitor, when the distance between the plates is increased ?

Ans. (i) No change (ii) increases (iii) No change (iv) increases.

18. Does the maximum charge given to a metallic sphere of radius R depend on whether it is hollow or solid ? Give reason for your answer.

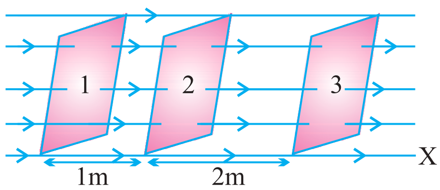
Ans. No, charge resides on the surface of conductor.

19. Two charges Q_1 and Q_2 are separated by distance r. Under what conditions will the electric field be zero on the line joining them (i) between the charges (ii) outside the charge?

Ans. (i) Charge are alike (ii) Unlike charges of unequal magnitude.

20. Obtain an expression for the electric field due to electric dipole at any point on the equatorial line.

21. The electric field component in the figure are $\vec{E}_x = 2x\hat{i}$, $\vec{E}_y = E_z = 0$. Calculate the electric flux through, (1, 2, 3) the square surfaces of side 5 m.



22. Calculate the work required to separate two charges 5μ*c* and – 2μ*c* placed at (– 3 cm, 0, 0) and (+ 3 cm, 0, 0) infinitely away from each other.

Ans. 1.5 J

23. What is electric field between the plates with the separation of 2 cm and (i) with air (ii) dielectric medium of dielectric constant K. Electric potential of each plate is marked in the following figure.

______________ 150 V

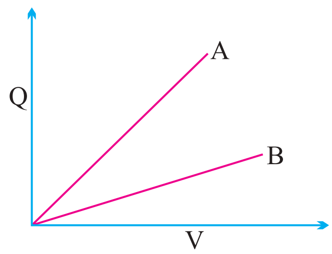
(i) _______________ – 50 V

Ans. $E_0 = 10^4\ NC^{-1}$, $E = \frac{10^4}{k}\ NC^{-1}$

24. A RAM (Random access Memory) chip a storage device like parallel plate capacitor has a capacity of 55pF. If the capacitor is charged to 5.3V, how many excess electrons are on its negative plate ?

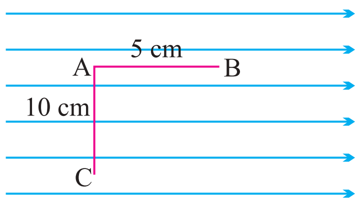
Ans. 1.8×10^9

25. The figure shows the Q (charge) versus V (potential) graph for a combination of two capacitors. identify the graph representing the parallel combination.



Ans. A represents parallel combination

26. Calculate the work done in taking a charge of 1 μC in a uniform electric field of 10 N/C from B to C given AB = 5 cm along the field and AC = 10 cm perpendicular to electric field.



Ans. $W_{AB} = W_{BC} = 50 \times 10^{-8}$ J. $W_{AC} = 0$J

27. Two charges – q and + q are located at points A (0, 0, – a) and B (0, 0, + a) respectively. How much work is done in moving a test charge from point P (7, 0, 0) to Q (– 3, 0, 0) ? (zero)

28. The potential at a point A is – 500 V and that at another point B is + 500 V. What is the work done by external agent to take 2 units (S.I.) of negative charge from B to A. $W_{BA} = 2000$ J

29. How does the (i) Potential energy of mutual interaction (ii) net electrostatic P.E. of two charges change when they are placed in an external electric field.

30. With the help of an example, show that Farad is a very large unit of capacitance.

31. What is meant by dielectric polarisation ? Why does the electric field inside a dielectric decreases when it is placed in an external field ?

32. In charging a capacitor of capacitance C by a source of emf V, energy supplied by the sources QV and the energy stored in the capacitor is ½QV. Justify the difference.

33. An electric dipole of dipole moment p, is held perpendicular to an electric field. If the dipole is released does it have (a) only rotational motion

(b) only translatory motion (c) both translatory and rotatory motion explain?

34. The net charge of a system is zero. Will the electric field intensity due to this system also be zero.

35. A point charge Q is kept at the intersection of (i) face diagonals (ii) diagonals of a cube of side a. What is the electric flux linked with the cube in (i) & (ii) ?

36. There are two large parallel metallic plates S_1 and S_2 carrying surface charge densities σ_1 and σ_2 respectively ($\sigma_1 > \sigma_2$) placed at a distance d apart in vacuum. Find the work done by the electric field in moving a point charge q a distance a ($a < d$) from S_1 and S_2 along a line making an angle $\pi/4$ with the normal to the plates.

37. Define mobility of electron in a conductor. How does electron mobility change when (i) temperature of conductor is decreased (ii) Applied potential difference is doubled at constant temperature ?

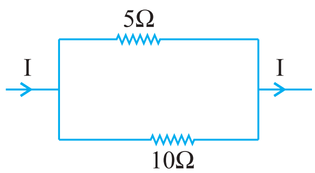
38. On what factors does emf of a cell depend?

39. What are superconductors ? Give one of their applications.

40. Two copper wires with their lengths in the ratio 1 : 2 and resistances in the ratio 1 : 2 are connected (i) in series (ii) in parallel with a battery. What will be the ratio of drift velocities of free electrons in two wires in (i) and (ii) ? **Ans.** (1 : 1, 2 : 1)

41. The current through a wire depends on time as $i = i_0 + at$ where $i_0 = 4A$ and $a = 2As^{-1}$. Find the charge crossing a section of wire in 10 seconds.

42. In the arrangement of resistors shown, what fraction of current I will pass through 5Ω resistor ? $\left(\frac{2I}{3}\right)$

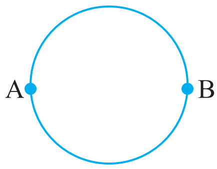


43. A 100W and a 200 W domestic bulbs joined in series are connected to the mains. Which bulb will glow more brightly ? Justify. (100W)

44. A 100W and a 200 W domestic bulbs joined in parallel are connected to the mains. Which bulb will glow more brightly ? Justify. (200W)

45. A battery has an emf of 12V and an internal resistance of 2Ω. Calculate the potential difference between the terminal of cell if (a) current is drawn from the battery (b) battery is charged by an external source.

46. A uniform wire of resistance R ohm is bent into a circular loop as shown in the figure. Compute effective resistance between diametrically opposite points A and B. **[Ans.** R/4]



47. A household circuit has a fuse of 5A rating calculate the maximum number of bulbs of rating 100W-220V each can be connected in this household circuit

Ans. Current drawn by each bulb $= \frac{p}{v} = \frac{100}{220} = \frac{5}{11}$ A No. of bulbs that can be safely used with 5A fuse $= \frac{5}{\frac{5}{11}} =$ 11 bulbs

48. Two heating coils, one of thin wire and other of thick wire, made of same material and of same length are connected in turn to a source of emf. Which one of the coils will produce more heat ?

Ans $P = \frac{V^2}{R}$, for same V, thicker wire has low resistance so it will more produce more heat.

49. A wheatstone bridge is in balance condition. Now if galvanometer and cell are interchanged, the galvanometer shows no deflection. Give reason. **[Ans.** Galvanometer will show no deflection. Proportionality of the arms are retained as the galvanometer and cell are interchanged.]

50. Give any two limitations of Ohm's law.

51. Which one of the two, an ammeter or a milliammeter has a higher resistance and why ? Ans. milliammeter

52. Name two factors on which the resistivity of a given material depends ?

53. If the electron drift speed is so small ($\sim 10^{-3}$ m/s) and the electron's charge is very small, how can we still obtain a large amount of current in a conductor.

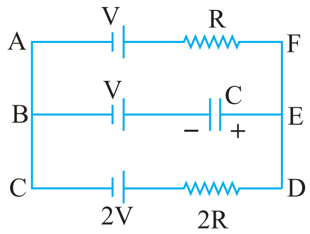
54. A battery of emf 2.0 volts and internal resistance 0.1Ω is being charged with a current of 5.0 A. What is the potential difference between the terminals of the battery ?

55. Five identical cells, each of emf E and internal resistance *r*, are connected in series to form (a) an open (b) closed circuit. If an ideal voltmeter is connected across three cells, what will be its reading ?

[Ans. (a) 3E; (b) zero]

56. An electron in a hydrogen atom is considered to be revolving around a proton with a velocity $\frac{e^2}{n}$ in a circular orbit of radius $\frac{n^2}{me^2}$. If I is the equivalent current, express it in terms of *m, e, n*.

57. In the given circuit, with steady current, calculate the potential drop across the capacitor in terms of V.



58. A cell of e.m.f. 'E' and internal resistance '*r*' is connected across a variable resistor 'R'. Plot a graph showing the variation of terminal potential 'V' with resistance 'R'. Predict from the graph the condition under which 'V' becomes equal to 'E'.

59. Winding of rheostat wire are quite close to each other why do not they get short circuted ?

Ans. The wire has a coating of insulating oxide over it which insulate the winding from each other.

60. The current I flows through a wire of radius r and the free electrons drift with velocity v_d. When a current 2I flows through the wire of same material but having double the radius, what will be the drift velocity of electrons in this wire

Ans.
$$v_d = \frac{I}{nAe} = \frac{I}{n.\pi r^2 e}$$

$$v_{d'} = \frac{2I}{n.\pi(2r)^2 e} = \frac{1}{2} v_d$$

SHORT ANSWER QUESTIONS (3 MARKS)

1. Define electrostatic potential and its unit. Obtain expression for electrostatic potential at a point P in the field due to a point charge.
2. Calculate the electrostatic potential energy for a system of three point charges placed at the corners of an equilateral triangle of side '*a*'.
3. What is polarization of charge ? With the help of a diagram show why the electric field between the plates of capacitor reduces on introducing a dielectric slab. Define dielectric constant on the basis of these fields.
4. Using Gauss's theorem in electrostatics, deduce an expression for electric field intensity due to a charged spherical shell at a point (i) inside (ii) on

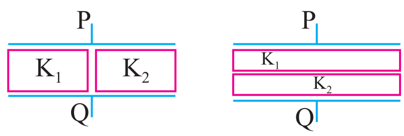
its surface (iii) outside it. Graphically show the variation of electric field intensity with distance from the centre of shell.

5. Three capacitors are connected first in series and then in parallel. Find the equivalent capacitance for each type of combination.

6. A charge Q is distributed over two concentric hollow sphere of radii r and R (R > r), such that their surface density of charges are equal. Find Potential at the common centre.

7. Derive an expression for the energy density of a parallel plate capacitor.

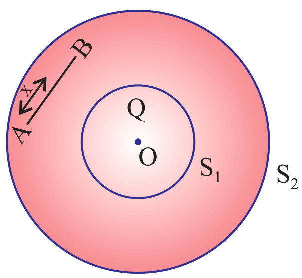
8. You are given an air filled parallel plate capacitor. Two slabs of dielectric constants K_1 and K_2 having been filled in between the two plates of the capacitor as shown in Fig. What will be the capacitance of the capacitor of initial area was A distance between plates d ?



Ans. $C_1 = (K_1 + K_2)C_0$

$$C_2 = \frac{K_1K_2C_0}{(K_1 + K_2)}$$

9. In the figure shown, calculate the total flux of the electrostatic field through the sphere S_1 and S_2. The wire AB shown of length l has a liner charge density λ given $\lambda = kx$ where x is the distance measured along the wire from end A.



Ans. Total charge on wire AB = $Q = \int_o^l \lambda dx = \int_o^l k\ x\ dx = \frac{1}{2}kl^2$

By Gauss's theorem.

Total flux through $S_1 = \frac{Q}{\epsilon_0}$

Total flux through $S_2 = \frac{Q + \frac{1}{2}kl^2}{\epsilon_0}$

10. Explain why charge given to a hollow conductor is transferred immediately to outer surface of the conductor.

11. Derive an expression for total work done in rotating an electric dipole through an angle θ in an uniform electric field. Hence calculate the potential energy of the dipole.

12. Define electric flux. Write its SI unit. An electric flux of f units passes normally through a spherical Gaussian surface of radius *r*, due to point charge placed at the centre.

(1) What is the charge enclosed by Gaussian surface ?

(2) If radius of Gaussian surface is doubled, what will be the flux through it ?

13. A conducting slab of thickness '*t*' is introduced between the plates of a parallel plate capacitor, separated by a distance *d* ($t < d$). Derive an expression for the capacitance of the capacitor. What will be its capacitance when $t = d$?

14. If a dielectric slab is introduced between the plates of a parallel plate capacitor after the battery is disconnected, then how do the following quantities change.

(i) Charge

(ii) Potential

(iii) Capacitance

(iv) Energy.

15. What is an equipotential surface ? Write three properties Sketch equipotential surfaces of

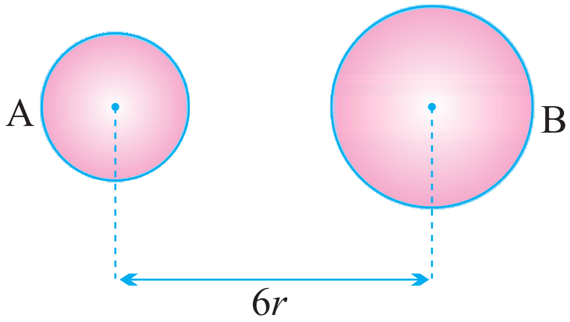
(i) Isolated point charge

(ii) Uniform electric field

(iii) Dipole

16. If charge Q is given to a parallel plate capacitor and E is the electric field between the plates of the capacitor the force on each plate is 1/2 QE and if charge Q is placed between the plates experiences a force equal to QE. Give reason to explain the above.

17. Two metal spheres A and B of radius r and $2r$ whose centres are separated by a distance of $6r$ are given charge Q, are at potential V_1 and V_2. Find the ratio of V_1/V_2. These spheres are connected to each other with the help of a connecting wire keeping the separation unchanged, what is the amount of charge that will flow through the wire ?



18. Define specific resistance. Write its SI unit. Derive an expression for resistivity of a wire in terms of its material's parameters, number density of free electrons and relaxation time.

19. A potential difference V is applied across a conductor of length L and diameter D. How are the electric field E and the resistance R of the conductor affected when (i) V is halved (ii) L is halved (iii) D is doubled. Justify your answer.

20. Define drift velocity. A conductor of length L is connected to a dc source of emf E. If the length of conductor is tripled by stretching it, keeping E constant, explain how do the following factors would vary in the conductor ?

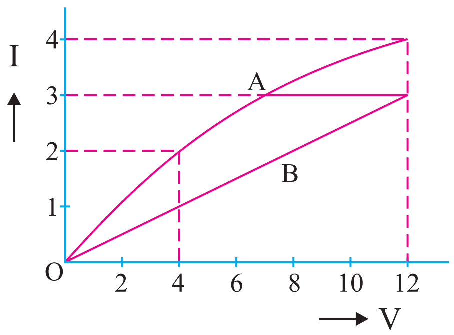
(i) Drift speed of electrons (ii) Resistance and (iii) Resistivity

21. Define conductivity of a substance. Give its SI units. How does it vary with temperature for (i) Copper (ii) Silicon ?

22. Two cells of emf E_1 and E_2 having internal resistance r_1 and r_2 are connected in parallel. Calculate E_{eq} and r_{er} for the combination.

23. The graph A and B shows how the current varies with applied potential difference across a filament lamp and nichrome wire respectively. Using the graph, find the ratio of the values of the resistance of filament lamp to the nichrome wire

(i) when potential difference across them is 12 V.



(ii) when potential difference across them is 4V. Give reason for the change in ratio of resistance in (i) and (ii).

24. Electron drift speed is estimated to be only a few mm/s for currents in the range of few amperes ? How then is current established almost the instant a circuit is closed.

25. Give three differences between e.m.f. and terminal potential difference of a cell.

26. Define the terms resistivity and conductivity and state their S. I. units. Draw a graph showing the variation of resistivity with temperature for a typical semiconductor.

27. The current flowing through a conductor is 2mA at 50V and 3mA at 60V. Is it an ohmic or non-ohmic conductor ? Give reason.

28. Nichrome and copper wires of same length and area of cross section are connected in series, current is passed through them why does the nichrome wire get heated first ?

29. Under what conditions is the heat produced in an electric circuit :

(i) directly proportional

(ii) inversely proportional to the resistance of the circuit.

LONG ANSWER QUESTIONS (5 MARKS)

1. Two charged capacitors are connected by a conducting wire. Calculate common potential of capacitors (ii) ratio of their charges at common potential. Show that energy is lost in this process.
2. Derive an expression for the strength of electric field intensity at a point on the axis of a uniformly charged circular coil of radius R carrying charge Q.
3. Derive an expression for potential at any point distant r from the centre O of dipole making an angle θ with the dipole.
4. Suppose that three points are set at equal distance r = 90 cm from the centre of a dipole, point A and B are on either side of the dipole on the axis (A closer to +ve charge and B closer to negative charge) point C which is on the perpendicular bisector through the line joining the charges. What would be the electric potential due to the dipole of dipole moment 3.6×10^{19} Cm at points A, B and C ?
5. Derive an expression for capacitance of parallel plate capacitor with dielectric slab of thickness $t(t < d)$ between the plates separated by distance d. How would the following (i) energy (ii) charge, (iii) potential be affected (a) if dielectric slab is introduced with battery disconnected, (b) dielectric slab is introduced after the battery is connected.
6. Derive an expression for torque experienced by dipole placed in uniform electric field. Hence define electric dipole moment.
7. State Gauss's theorem. Derive an expression for the electric field due to a charged plane sheet. Find the potential difference between the plates of a parallel plate capacitor having surface density of charge 5×10^{-8} Cm^{-2} with the separation between plates being 4 mm.
8. Define current density. Give its SI unit. Whether it is vector or scalar ? How does it vary when (i) potential difference across wire increases (ii) length of wire increases (iii) temperature of wire increases (iv) Area of cross-section of wire increases justify your answer.

9. Using Gauss's theorem obtain an expression for electric field intensity due to a plane sheet of charge. Hence obtain expression for electric field intensity in a parallel plate capacitor.

10. Write any four important results regarding electro statics of conductors.

11. State Kirchhoffs's rules for electrical networks. Use them to explain the principle of Wheatstone bridge for determining an unknown resistance. How is it realized in actual practice in the laboratory ? Write the formula used.

12. For three cells of emf E_1, E_2 and E_3 with internal resistance r_1, r_2, r_3 respectively connected in parallel, obtain an expression for net internal resistance and effective current. What would be the maximum current possible if the emf of each cell is E and internal resistance is r each ?

13. Derive an expression for drift velocity of the electron in conductor. Hence deduce ohm's law.

14. How does the internal resistance of a cell change in the following cases-

(i)When concentration of electrolyte is increased

(ii)When area of the anode is increased

(iii)When temperature of electrolyte is decreased

Ans. (i) increases (ii) decrease (iii) increases

15. Explain how does the conductivity of a :

(i) Metallic conductor

(ii) Semi conductor and

(iii) Insulator varies with the rise of temperature.

16. Derive expression for equivalent e.m.f. and equivalent resistance of a :

(a) Series combination

(b) Parallel combination

of three cells with e.m.f. E_1, E_2, E_3 & internal resistances r_1, r_2, r_3 respectively.

17. Deduce the condition for balance in a Wheatstone bridge, using the Kirchhoff's law

NUMERICALS

1. What should be the position of charge $q = 5\mu C$ for it to be in equilibrium on the line joining two charges $q_1 = -4\ \mu C$ and $q_2 = 16\ \mu C$ separated by 9 cm. Will the position change for any other value of charge q ? (9 cm from – 4 μC)
2. Two point charges 4e and e each, at a separation r in air, exert force of magnitude F. They are immersed in a medium of dielectric constant 16. What should be the separation between the charges so that the force between them remains unchanged. (1/4 the original separation)
3. Two capacitors of capacitance 10 μF and 20 μF are connected in series with a 6V battery. If E is the energy stored in 20 μF capacitor what will be the total energy supplied by the battery in terms of E. (6E)
4. Two point charges 6 μC and 2 μC are separated by 3 cm in free space. Calculate the work done in separating them to infinity. (3. 6 joule)
5. ABC is an equilateral triangle of side 10 cm. D is the mid point of BC charge 100 μC,– 100μC and 75 μC are placed at B, C and D respectively. What is the force experienced by a 1 μC positive charge placed at A ?

$$(90\sqrt{2} \times 10^3\ N)$$

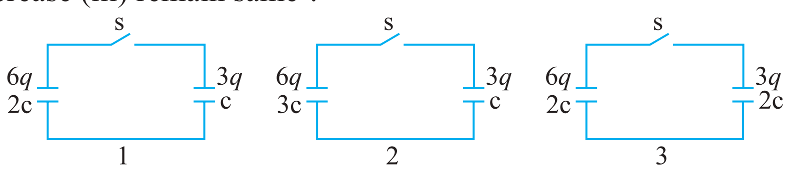
6. A point charge of 2 μC is kept fixed at the origin. Another point charge of 4 μC is brought from a far point to a distance of 50 cm from origin. (a) Calculate the electrostatic potential energy of the two charge system. Another charge of 11 μC is brought to a point 100 cm from each of the two charges. What is the work done ? (a) 144×10^{-3} J
7. A 5 MeV α particle is projected towards a stationary nucleus of atomic number 40. Calculate distance of closest approach. (1.1×10^{-4} m)

8. To what potential must a insulated sphere of radius 10 cm be charged so that the surface density of charge is equal to 1 μC/m^2. (1.13 × 10^{4}V)

9. A slab of material of dielectric constant K has the same area as the plates of parallel plate capacitor but its thickness is $\frac{3d}{4}$, where d is separation between plates, How does the capacitance change when the slab is inserted between the plates ?

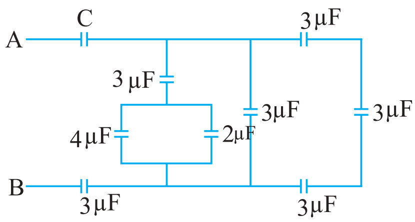
10. A point charge developes an electric field of 40 N/C and a potential difference of 10 J/C at a point. Calculate the magnitude of the charge and the distance from the point charge. (2.9 × 10^{-10} C, 25 cm)

11. Figure shows three circuits, each consisting of a switch and two capacitors initially charged as indicated. After the switch has been closed, in which circuit (if any) will the charges on the left hand capacitor (i) increase (ii) decrease (iii) remain same ?



(1 remains unchanged, 2 increases, 3 decreases).

12. For what value of C does the equivalent capacitance between A and B is 1μF in the given circuit.



All capacitance given in micro farad **Ans.** 2 μF

13. A pendulum bob of mass 80 mg and carrying charge of 3 × 10^{-8} C is placed in an horizontal electric field. It comes to equilibrium position at an angle of 37° with the vertical. Calculate the intensity of electric field. (g = 10m/s^2) (2 × 10^4 N/C)

14. Eight charged water droplets each of radius 1 mm and charge 10 × 10^{-10} C coalesce to form a single drop. Calculate the potential of the bigger drop.

(3600 V)

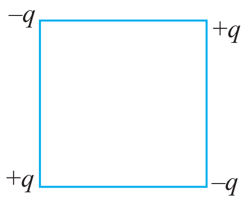
15. What potential difference must be applied to produce an electric field that can accelerate an electron to 1/10 of velocity of light. $(2.6 \times 10^3 \text{ V})$

16. A 10 μF capacitor can withstand a maximum voltage of 100 V across it, whereas another 20 μF capacitor can withstand a maximum voltage of only 25 V. What is the maximum voltage that can be put across their series combination ?

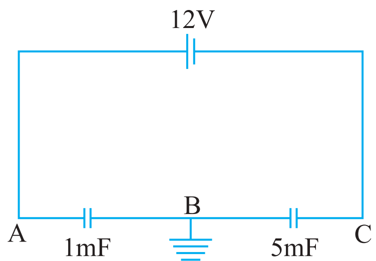
17. Three concentric spherical metallic shells A < B < C of radii *a, b, c* $(a < b < c)$ have surface densities $\sigma, -\sigma$ and σ respectively. Find the potential of three shells A, B and C (ii). If shells A and C are at the same potential obtain relation between *a, b, c*.

18. Four point charges are placed at the corners of the square of edge *a* as shown in the figure. Find the work done in disassembling the system of charges.

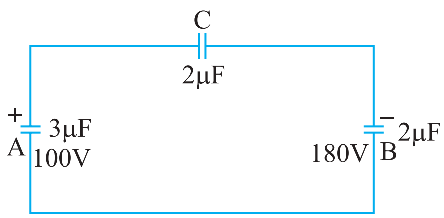
$$\left[\frac{kq^2}{a}(\sqrt{2}-4)\right] \text{J}$$



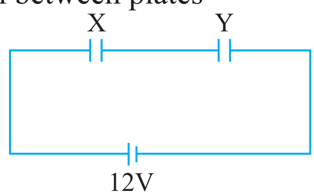
19. Find the potential at A and C in the following circuit :



20. Two capacitors A and B with capacitances 3 μF and 2 μF are charged 100 V and 180 V respectively. The capapitors are connected as shown in the diagram with the uncharged capacitor C. Calculate the (i) final charge on the three capacitors (ii) amount of electrostatic energy stored in the system before and after the completion of the circuit.



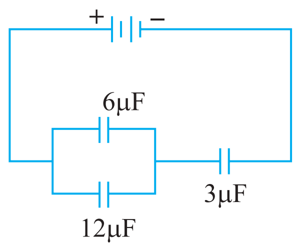
21. Fig. shows two parallel plate capacitors X and Y having same area of plates and same separation between them : X has air while Y has dielectric of constant 4 as medium between plates



(a) calculate capacitance of each capacitor, if equivalent capacitance of combination is 4μF (b) calculate potential difference between plate X and Y (c) what is the ratio of electrostatic energy stored in X & Y.

Ans. (a) 5μF, 20μF, (b) 9.6V, 2.4V (c) 4

22.



In the following arrangement of capacitors, the energy stored in the 6μF capacitor is E.

Find :

(i) Energy stored in 12 μF capacitors.

(ii) Energy stored in 3μF capacitor.

(iii) Total energy drawn from the battery.

Ans. (i) $E = \frac{1}{2}CV^2 = \frac{6}{2} \times 10^{-6} V^2 = 3 \times 10^{-6} V^2$

$$V^2 = \frac{E}{3 \times 10^{-6}}$$

Energy stored in 12μF capacitor = $\frac{1}{2}CV^2$

$$= \frac{1}{2} \times 12 \times 10^{-6} \times \frac{E}{3 \times 10^{-7}}$$

$$= 2E$$

(ii) Charge on 6μF capacitor $\left[\because E = \frac{1}{2}\frac{Q^2}{C}\right]$

$$Q_1 = \sqrt{2EC}$$

$$= 2\sqrt{3}E \times 10^{-3} C$$

Charge on 12μF capacitor

$$Q_2 = 2\sqrt{2CE}$$

$$= \sqrt{2 \times 12 \times 10^{-6} \times 2E}$$

$$= 4\sqrt{3E} \times 10^{-3} C$$

Charge on 3μF capacitor $Q = Q_1 + Q_2$

$$= 6\sqrt{3E} \times 10^{-3}$$

Energy stored in 3μF capacitor

$$= \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2} \times \frac{36 \times 3E \times 10^{-6}}{3 \times 10^{-6}}$$

$$= 18E$$

(ii) Capacitance of parallel combination = 18μF

Charge on parallel combination Q = CV

$$= 18 \times 10^{-6} V$$

$$\text{Charge on } 3\mu F = Q = 3 \times 10^{-6} V_1$$

$$18 \times 10^{-6} V = 3 \times 10^{-6} V_1$$

$$V_1 = 6V$$

Energy stored in 3μF capacitor = $\frac{1}{2}CV_1^2$

$$= \frac{1}{2} \times 3 \times 10^{-6} \times \frac{E \times 36}{3 \times 10^{-6}}$$

$$= 18E$$

(iii) Total eEnergy drawn = E + 2E + 18E = 21E

23. The charge passing through a conductor is a function of time and is given as $q = 2t^2 - 4t + 3$ milli coulomb. Calculate (i) current through the conductor (ii) potential difference across it at $t = 4$ second. Given resistance of conductor is 4 ohm. **Ans.** I = 12A, V = 48 V

24. The resistance of a platinum wire at a point 0°C is 5.00 ohm and its resistance at steam point is 5.40Ω. When the wire is immersed in a hot oil bath, the resistance becomes 5.80Ω. Calculate the temperature of the oil bath and temperature coefficient of resistance of platinum.

Ans. $\alpha = 0.004°\ C^{-1}$; T = 200°C

25. Three identical cells, each of emf 2V and internal resistance 0.2 ohm, are connected in series to an external resistor of 7.4 ohm. Calculate the current in the circuit and the terminal potential difference across an equivalent.

Ans. I = 0.75; V = 5.55 V

26. A storage battery of emf 12V and internal resistance of 1.5Ω is being charged by a 12V supply. How much resistance is to be put in series for charging the battery safely, by maintaining a constant charging current of 6A. **Ans.** R = 16.5 Ω

27. Three cells are connected in parallel, with their like poles connected together, with wires of negligible resistance. If the emf of the cell are 2V, 1V and 4V and if their internal resistance are 4Ω, 3Ω and 2 Ω respectively, find the current through each cell. $\left[\textbf{Ans.}\ I_1 = \frac{-2}{13}A, I_2 = \frac{-7}{13}A,\ I_3 = \frac{9}{13}A\right]$

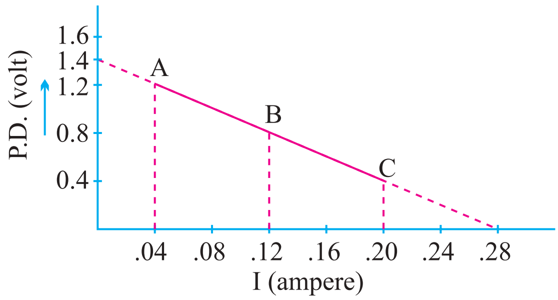
28. A 16 ohm resistance wire is bent to form a square. A source of emf 9 volt is connected across one of its sides. Calculate the potential difference across any one of its diagonals. **Ans.** 1V

29. A length of uniform 'heating wire' made of nichrome has a resistance 72 Ω. At what rate is the energy dissipated if a potential difference of 120V is applied across (a) full length of wire (b) half the length of wire (wire is cut into two). Why is it not advisable to use the half length of wire ?

Ans. (a) 200W, (b) 400W, 400W >> 200W but since current becomes large so it is not advisable to use half the length

30. Potential difference across terminals of a cell are measured (in volt) against different current (in ampere) flowing through the cell. A graph was drawn which was a straight line ABC. Using the data given in the graph. Determine (i) the emf. (ii) The internal resistance of the cell.

Ans. $r = 5\Omega$ emf = 1.4V

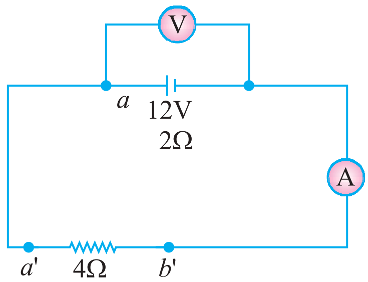


31. Four cells each of internal resistance 0.8Ω and emf 1.4V, are connected (i) in series (ii) in parallel. The terminals of the battery are joined to the lamp of resistance 10Ω. Find the current through the lamp and each cell in both the cases.

Ans. $I_s = 0.424A$, $I_p = 0.137A$ current through each cell is 0.03A

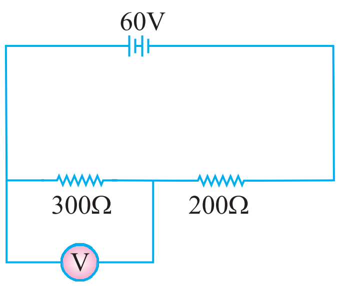
32. In the figure, an ammeter A and a resistor of resistance R = 4Ω have been connected to the terminals of the source to form a complete circuit. The emf of the source is 12V having an internal resistance of 2Ω. Calculate voltmeter and ammeter reading.

Ans. Voltmeter reading : 8V, Ammeter reading = 2A

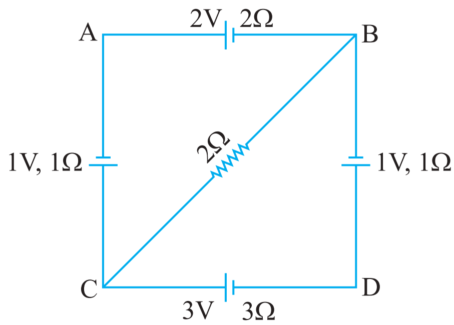


33. In the circuit shown, the reading of voltmeter is 20V. Calculate resistance of voltmeter. What will be the reading of voltmeter if this is put across 200Ω resistance ?

$\left[\textbf{Ans. } R_V = 150\Omega,\ V = \frac{40}{3}V\right]$



34. For the circuit given below, find the potential difference b/w points B and D. **Ans.** 1.46 Volts

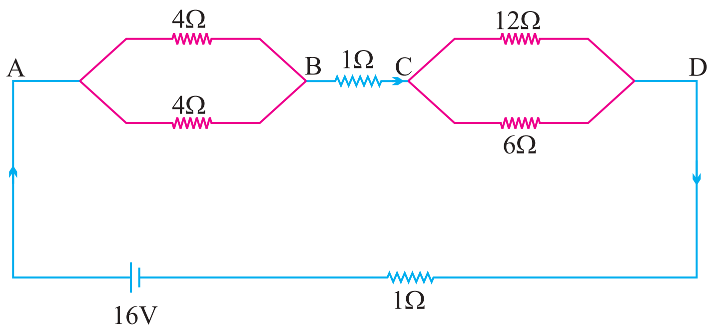


35. A battery of emf 10V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 0.5A, what is the resistance of the resistor ? What is the terminal voltage of the battery when the circuit is closed ?

36. A network of resistance is connected to a 16V battery with internal resistance of 1Ω as shown in Fig. on next page.

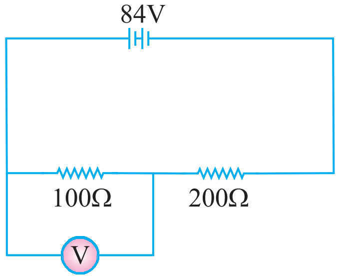
(i) Obtain the current in each resistor.

(ii) Obtain the voltage drop V_{AB}, V_{BC} & V_{CD}.

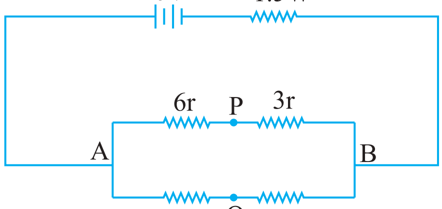


37. The number density of conduction electrons in a Copper Conductor estimated to be $8.5 \times 10^{28}\ m^{-3}$. How long does an electron take to drift from one end of a wire 3.0 m long to its other end ? The area of cross section of the wire is $2.0 \times 10^{-6}\ m^2$ and it is carrying a current of 3.0 A.

38. A voltmeter of resistance 400Ω is used to measure the potential difference across the 100Ω resistor in the circuit shown in figure. What will be the reading of voltmeter.



39. Find magnitude of current supplied by battery. Also find potential difference between points P and Q in the given fig. **Ans.**1A, 1.5V

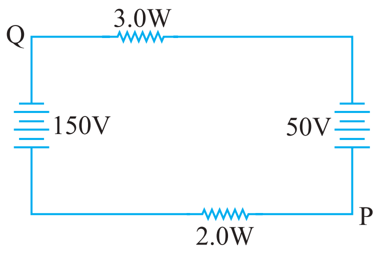


40. A copper wire of length 3 m and radius r is nickel plated till its radius becomes $2r$. What would be the effective resistance of the wire, if specific resistance of copper and nickel are ρ_c and ρ_n respectively.

[Hint : $R_c = \rho_c \dfrac{l}{\pi r^2}$; $R_n = \rho_n \dfrac{l}{\pi(2r)^2 - \pi r^2}$

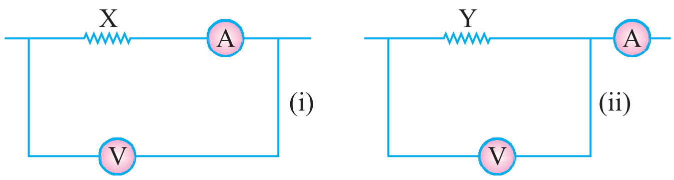
$R = \dfrac{R_C\, R_n}{R_C + R_n}$. $\left[\textbf{Ans. } R = \dfrac{3\rho_n \rho_c}{\pi r^2 (3\rho_c + \rho_n)} \right]$

41. In the figure, if the potential at point P is 100V, what is the potential at point Q ?



Ans. – 10V

42. Given two resistors X and Y whose resistances are to be determined using an ammeter of resistance 0.5Ω and a voltmeter of resistance 20 kΩ. It is known that X is in the range of a few ohms, while Y is in the range of several thousand ohm. In each case, which of the two connection shown should be chosen for resistance measurement ?

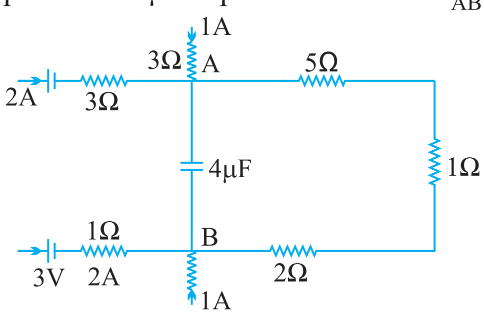


Ans. Small resistance : X will be preferred; large resistance : Y will be preferred

43. When resistance of 2Ω is connected across the terminals of a battery, the current is 0.5A. When the resistance across the terminal is 5Ω, the current is 0.25A. (i) Determine the emf of the battery (ii) What will be current drawn from the cell when it is short circuited.

Ans. E = 1.5 V, I = 1.5A

44. A part of a circuit in steady state, along with the currents flowing in the branches and the resistances, is shown in the figure. Calculate energy stored in the capacitor of 4μF capacitance. **Ans.** $V_{AB} = 20V, U = 8 \times 10^{-4}$ J

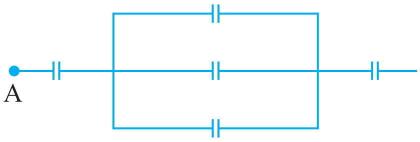


45. A voltmeter with resistance 500Ω is used to measure the emf of a cell of internal resistance 4Ω. What will be the percentage error in the reading of the voltmeter. **Ans.** 0.8%

HINTS FOR 2 MARKS QUESTIONS

10. $\frac{t_e}{t_p} = \sqrt{\frac{2sm_e}{eE}} \Big/ \sqrt{\frac{2sm_p}{eE}} = \sqrt{\frac{m_e}{m_p}}$

14.



$$\frac{1}{Cs} = \frac{1}{2} + \frac{1}{6} + \frac{1}{2} = \frac{1}{6}$$

$$Cs = \frac{6}{7}\ \mu F$$

21. $\varphi = \overline{E}.\overline{ds} = 2x\hat{i}.ds\hat{i} = 2x.ds$

$\varphi_1 = 0,\ \varphi_2 = 50$ Vm, $\varphi_3 = 150$ Vm

28. $W_{BA} = q_o\ (V_B - V_A) = 2 \times 1000 = 2000$ J

32. In the capacitor the voltage increases from O to V, hence energy stored will correspond to average which will be ½ QV. While the source is at constant emf V. So energy supplied will be QV. The difference between the two goes as heat and emf radiations.

35. Construct a closed system such that charge is enclosed within it. For the charge on one face, we need to have two cubes place such that charge is on the common face. According to Gauss's theorem total flux through the Gaussian surface (both cubes) is equal to $\frac{q}{2\varepsilon_0}$. Therefore the flux through one cube will be equal to $\frac{q}{2\varepsilon_0}$.

36. Work done = $fd \cos\theta = qEd\cos\theta = \frac{q(\sigma_1 - \sigma_2)}{\varepsilon_0}\frac{a}{\sqrt{2}}$

40. $\frac{R_1}{R_2} = \frac{l I_1}{A_1} \times \frac{A_2}{l I_2} \Rightarrow \frac{I_1 A_2}{A_1 I_2} \Rightarrow \frac{1}{2}, \frac{I_1}{I_2} = \frac{1}{2} \therefore \frac{A_2}{A_1} = 1$

(i) in series neA, $(V_d) = neA_2(V_d)_2 \Rightarrow \frac{(V_d)_1}{(V_d)_2} = 1$

(ii) $i_1R_1 = i_2R_2 \Rightarrow \frac{(V_d)_1}{(V_d)_2} = \frac{2}{1}$

42. Current through $5\Omega = \left(\frac{10}{5+10}\right)I = \frac{2I}{3}$

56. $I = \frac{\text{Charge circulating}}{\text{Time for one revolution}} = \frac{e}{2\pi r / v}$ $\quad v \longrightarrow$ speed

$$= \frac{ev}{2\pi r}$$

$$= \frac{ee^2me^2}{n2\pi n^2} = \frac{me^5}{2\pi n^3}$$

57. In steady state the branch containing C can be omitted hence the current

$$I = \frac{2V - V}{R + 2R} = \frac{V}{3R}$$

For loop EBCDE

$$-V_C - V + 2V - 1\,(2R) = 0$$

$\Rightarrow$ $$V_C = \frac{V}{3}$$

$$\frac{V}{l}$$

51. Milliammeter. To produce large deflection due to small current we need a large number of turns in armature coil $\Rightarrow$ Resistance increases.

52. Temperature

53. The electron number density is of the order of $10^{29}\ m^{-3}$, $\Rightarrow$ the net current can be very high even if the drift spread is low.

54. $V = E + ir$

$$= 2 + 0.15$$

$$= 2.15V$$

HINTS FOR NUMERICALS

9.

$$V = E_o\left(\frac{d}{4}\right) + \frac{E_o}{K}\left(\frac{3d}{4}\right) = E_o d\left(\frac{K+3}{4K}\right)$$

$$V = V_o\left(\frac{K+3}{4K}\right)$$

$$C = \frac{Q_o}{V} = \frac{4K}{K+3}\frac{Q_o}{V_o} = \frac{4K}{K+3}Co$$

14.

$$r = 1 \text{ mm}$$

$$\frac{4}{3}\pi R^3 = 8\cdot\frac{4}{3}\pi r^3 \Rightarrow R = 2 \text{ mm}$$

$$Q = 8q = 8 \times 10 \times 10^{-10} \text{ C}$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

$$= \frac{9 \times 10^9 \times 8 \times 10^{-9}}{2 \times 10^{-3}} = 36000 \text{ Volt}$$

21.

$$C_x = C, C_y = KC = 4C$$

$$\frac{C_x C_y}{C_x + C_y} = \frac{4}{5}C = 4 \Rightarrow C = 5\mu f$$

(a) $Ceq = C_x = 5\mu f$

$C_y = 20\mu f$

(b) $V + \frac{V}{4} = 12$ ($V_x = V$, $V_y = \frac{V}{4}$ as q constant)

$V = 9.6$ Volt, $V_x = 9.6$ Volt, $V_y = 2.4$ Volt

(c)

$$\frac{U_x}{U_y} = \frac{\frac{1}{2}C_x V_{x^2}}{\frac{1}{2}C_y (V_y)^2} = 4$$

HINTS FOR 3 MARKS QUESTIONS

16. If E′ be the electric field due to each plate (of large dimensions) then net electric field between them

$$E = E' + E' \Rightarrow E' = E/2$$

Force on change Q at some point between the plates F = QE

Force on one plate of the capacitor due to another plate F′ = QE′ = QE/2

17.

$$V_1 = \frac{kq}{r} + \frac{kq}{6r} = \frac{7kq}{6r}$$

$$V_2 = \frac{kq}{2r} + \frac{kq}{6r} = \frac{3kq + kq}{6r} = \frac{4kq}{6r}$$

$$\frac{V_1}{V_2} = \frac{7}{4}$$

$$V_{common} = \frac{2q}{4\pi\varepsilon_0(r + 2r)} = \frac{2q}{12\pi\varepsilon_0 r} = V'$$

Charge transferred equal to

$$q' = C_1V_1 - C_1V' = \frac{r}{k}.\frac{kq}{r} - \frac{r}{k}.\frac{k_2q}{3r}$$

$$= q - \frac{2q}{3} = \frac{q}{3}.$$

27.

$$R_1 = \frac{V_1}{I_1} = \frac{50}{2 \times 10^{-3}} = 25{,}000\Omega$$

$$R_2 = \frac{V_2}{I_2} = \frac{60}{3 \times 10^{-3}} = 20{,}000\Omega.$$

As resistance changes with I, therefore conductor is non ohmic.

28. Rate of production of heat, $P = I^2R$, for given l, P × R, ∴ $\rho_{nichrome} > \rho_{cu}$

∴ $R_{Nichrome} > R_{cu}$ of same length and area of cross section.

29. (i) If I in circuit is constant because $H = I^2 Rt$

(ii) If V in circuit is constant because $H = \frac{V^2}{R}t$

NUMERICALS

17.

$$V_A = k\left[\frac{q_1}{a} + \frac{q_2}{b} + \frac{q_3}{c}\right]$$

$$= k\,4\pi a\sigma - k4\pi b\sigma + k4\pi c\sigma$$

$$= 4\pi a\sigma\,(a - b + c)$$

$$= \frac{\sigma}{\varepsilon_0}(a - b + c)$$

$$V_B = k\left[\frac{q_1}{b} + \frac{q_2}{b} + \frac{q_3}{c}\right] = k\left[\frac{4\pi a^2\sigma}{b} - 4\pi kb\sigma + 4\pi kc\sigma\right]$$

$$= \frac{\sigma}{\varepsilon_0}\left(\frac{a^2}{b} - b^2 + c^2\right)$$

$$V_C = \frac{\sigma}{\varepsilon_0 c}\left(a^2 - b^2 + c^2\right)$$

When $V_A = V_C$

$$\frac{\sigma}{\varepsilon_0}(a - b + c) = \frac{\sigma}{\varepsilon_0 C}(a^2 - b^2 + c^2)$$

$$ac - bc + c^2 = a^2 - b^2 + c^2$$

$$c\,(a - b) = (a - b)\,(a + b)$$

$$c = a + b$$

19. $Q = CV$

Total charge Q = Total capacitance in series × voltage

$$= \left(\frac{5}{6} \times 10^{-3}\right) \times 12 = 10 \times 10^{-3} \text{ coulomb}$$

$$V_{AB} = \frac{Q}{c_1} = \frac{10 \times 10^{-3}}{1 \times 10^{-3}} = 10\text{V}$$

$$V_{BC} = \frac{Q}{c_2} = \frac{10 \times 10^{-3}}{5 \times 10^{-3}} = 2\text{V}.$$

When B is earthed $V_B = 0$, $V_A = 10V$ and $V_C = -2V$.

21. Before dielectric is introduced.

$$E_A = \frac{1}{2}CV^2; \qquad E_B = \frac{1}{2}CV^2$$

$$E = E_A + E_B = CV^2$$

After disconnecting the battery and then introducing dielectric

$$E'_A = \frac{1}{2}(3C)V^2$$

$$E'_B = \frac{Q^2}{2C} = \frac{(CV)^2}{2 \times 3C}$$

$$= \frac{1}{3}\left(\frac{1}{2}CV^2\right),$$

$$E' = E'_A + E'_B$$

$$\frac{E'}{E} = \frac{5}{3}.$$

35.

$$E = I(R + r)$$

$$10 = 0.5(R + 3)$$

$$R = 17\Omega$$

$$V = E - Ir = 10 - 0.5 \times 3 = 8.5V$$

36.

$$Req = 7W$$

$$I_{4\Omega} = 1A, I_{1\Omega} = 2A, I_{12\Omega} = \frac{2}{3}A, I_{6\Omega} = \frac{4}{3}A,$$

$$V_{AB} = 4V, V_{BC} = 2V, V_{CD} = 8V$$

37. $$I = enAV_d = \frac{l}{t}$$

$$t = \frac{en\,Al}{1} = 2.7 \times 10^4 \text{ s}$$

38. $$I = \frac{84}{\left(\frac{100 \times 400}{100 + 400}\right) + 200} = \frac{84}{280} = 0.3A$$

P.d. across voltmeter & 100Ω combination

$$= 0.3 \times \frac{100 \times 400}{100 + 400} = 24V.$$

39. $$R_{AB} = 4.5\Omega$$

$$i = \frac{E}{R_{AB} + 1.5} = \frac{6}{6} = 1A.$$

$$i_{AP} = i_{AQ} = 0.5A, V_{AP} = 3 \Rightarrow V_p = 3 \text{ Volt}$$

$$V_{AQ} = 1.5\ V_Q = 4.5 \text{ Volt}$$

$$V_Q - V_P = 1.5 \text{ Volt}$$